Building Automation

- That digital thing that we use everyday without even realizing it

- **Building automation** is the automatic centralized **control** of a **building's** HVAC (heating, ventilation and air conditioning), electrical, lighting, shading, Access **Control**, Security Systems, and other interrelated systems through a **Building** Management System (BMS) or **Building Automation** System (BAS).

- https://en.wikipedia.org/wiki/Building_automation#:~:text=Building%20automation%20is%20the%20automatic,Building%20Automation%20System%20(BAS).

Building automation

That digital thing, we all use every day without realizing it

Building IoT and our digital journey, Salvatore Cataldi, November 2020.

4

The estimated us $ size of the global building automation market

69.6 billion US dollars

What is the estimated US$ size of the global building automation market?

Asked by **Salvatore Cataldi** about a minute ago   🔒 Private

○ 3,8 billions US dollars

○ 69,6 billions US dollars

○ 180,1 billions US dollars

Why do we need to do building automation

- We spend most of our times in a building

- Even if we interact with the building by repeating actions that can be "recognized" and "catalogued"

- The building changes as we change

- The way we work changes and the place where we do our work changes

- In a cycling iteration between the rising of new needs and the offer of new technological possibilities

- The above are all the reasons as to why we felt the need for building automation.

Why?

The automated building:
not only comfort and energy

- We spend most of our time in a building.

- Even if we interact with the building by repeating actions that can be "recognized" and "catalogued".

- the building changes as we change.

- The way we work changes and the place where we do our work changes

- in a cyclical iteration between the rising of new needs and the offer of new technological possibilities.

Courtesy of Deloitte Insights, The future of work in technology

6

Automated control in building

- Building automation arises from the opportunity to replace the human in the execution of simple actions inside the building.

- Left is a temperature sensor. A **temperature sensor** is an electronic device that measures the **temperature** of its environment and converts the input data into electronic data to record, monitor, or signal **temperature** changes.

- Microprocessor Controller: **Microprocessor** consists of only a Central Processing Unit, whereas Micro **Controller** contains a CPU, Memory, I/O all integrated into one chip. **Microprocessor** is used in Personal Computers whereas Micro **Controller** is used in an embedded system.

- Actuator: An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover". An actuator requires a control signal and a source of energy.


Automated Control

...in buildings...

- Building automation arises from the opportunity to replace the human in the execution of simple actions inside the building

automatisation
(de automatiser)

LAROUSSE
ENCYCLOPÉDIE

Suppression totale ou partielle de l'intervention humaine dans l'exécution de tâches diverses, industrielles, agricoles, domestiques, administratives ou scientifiques.

ing-IoT and our digital journey, Salvatore Cataldi, November 2020.

7
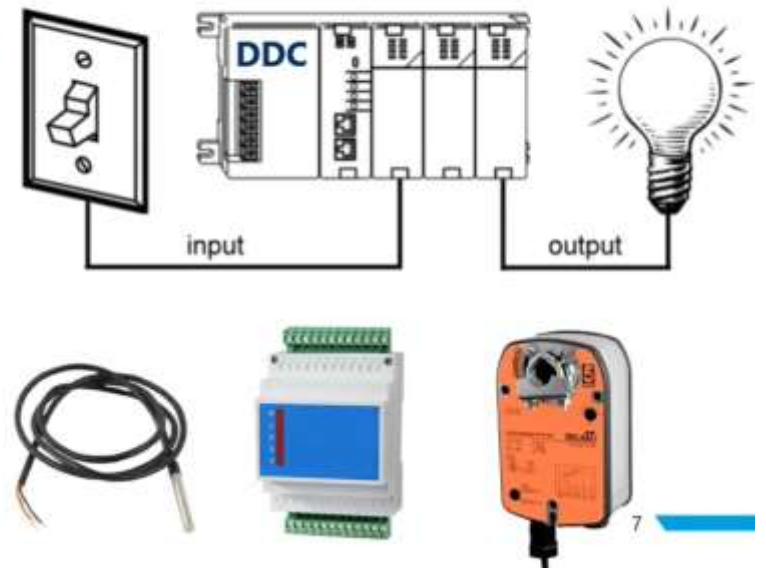
Sensors, controllers and actuators

- In HVAC air handling units can be made up of several tens of components. Heating, ventilation, and air conditioning(HVAC) is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality.

- The relationships among the components are not exclusively linked to logical operations but above all to algorithms of regulations

- Several machines have a local controller and are coordinated by higher level controllers

- We have to physically connect, inputs and outputs to the controller in order to manage that single information for each connection.
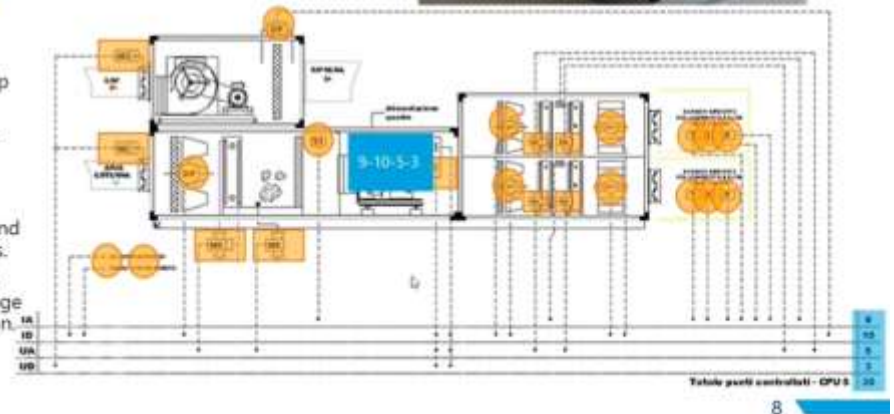
Controllers and intelligent sensors and actuators

- A **bus** is a subsystem that is used to connect computer components and transfer data between them. ...
A **bus** may be parallel or serial. Parallel **buses** transmit data across multiple wires. Serial **buses** transmit data in bit-serial format.

Controllers and intelligent sensors and actuators

New functionalities thanks to digital communication.

Building-IoT and our digital journey. Salvatore Cataldi. November 2020

9
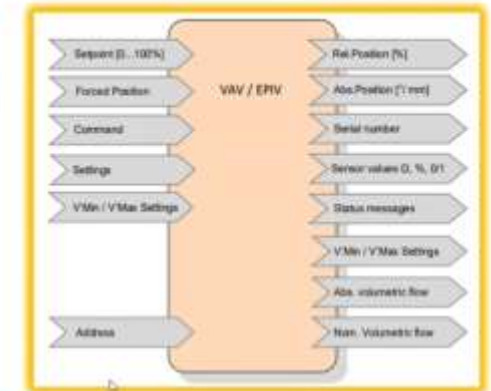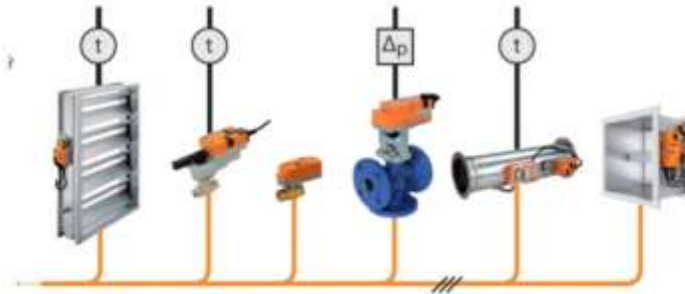
Digital Communication

Fieldbus and client server systems

- Digital communication, on bus or network, began with protocols that presupposed knowledge in detail of the memory of each connected device

- Basically it was imagined to read and write in specific regions of the memory of the devices and the devices were mostly passively subjected to the operation of reading or writing.

- This is the case of Modbus protocol in 1970

- Modbus is a data communications protocol originally published by Modicon in 1979 for use with its programmable logic controllers. Modbus has become a de facto standard communication protocol and is now a commonly available means of connecting industrial electronic devices.
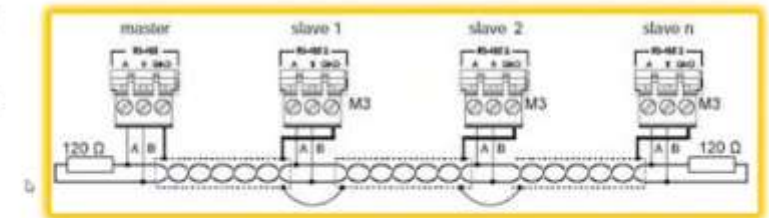
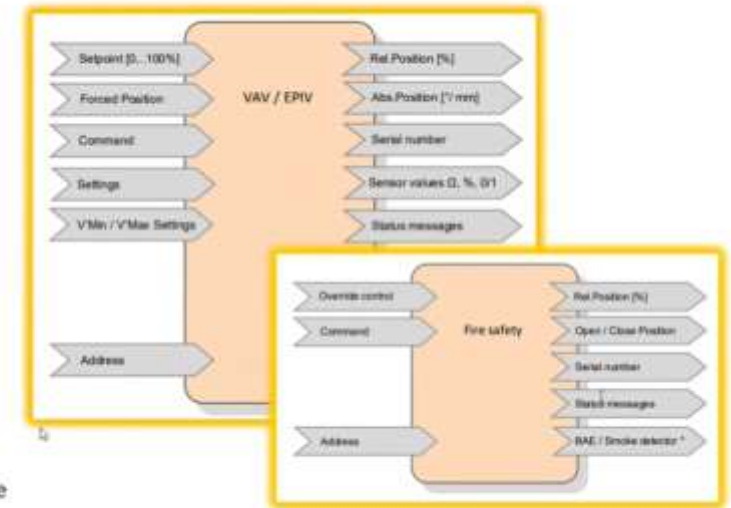# Object-Oriented protocols in digital communication

Digital Communication

Object-Oriented Protocols

- As the computing capabilities of the controllers and their miniaturization increase, the concept of "software object" and communication between software objects have developed and become established.

This allowed:

- to distribute intelligence in the System
- to diversify the development of controllers
- to verify the control software models in view of the cooperation between controllers

Object-Oriented Protocols in digital communication contd..

Digital Communication

Object-Oriented Protocols

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This allowed:

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This is the case with the BACnet protocol. We are at the end of the eighties

Architecture of a BACS Building Automation and Control System
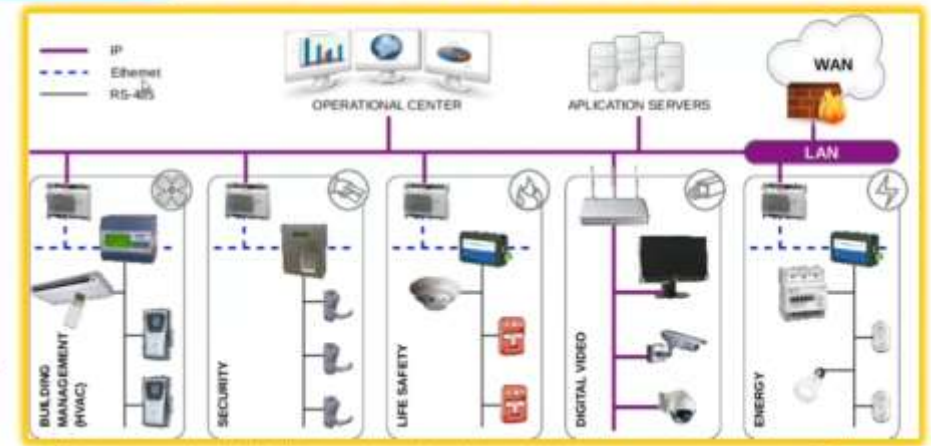
From the device to its digital twin

- A digital twin is a digital replica of a living or non-living physical entity. Digital twin refers to a digital replica of potential and actual physical assets, processes, people, places, systems and devices that can be used for various purposes.

- We have an actuator, a physical device, and we integrate digital signal processing component within it. Later we can introduce different kind of protocols

From the device... ...to its digital twin

- BACnet
- Modbus
- MP BUS TECHNOLOGY BY BELIMO
- KNX
- LonMark

- it is a digital representation of the device
- contains historical information, data logs
- can be accessed by users and services at the same time
- can be integrated into digital ecosystems

13

Internet of things
Digital Twin, Digital Ecosystem and Building IOT

Internet of things

Digital Twin, Digital Ecosystem and Building IoT

- Actuators, controllers and sensors are installed in different buildings.

- They are connected locally in a BMS and there may be direct connections between buildings.

- The Internet represents a valuable infrastructure to connect devices in buildings even far away from each other.

- Devices that are part of a digital ecosystem acquire additional value because they benefit from the experience of all installed devices, not only locally.

https://www.belim

14

ilding-IoT and our digital journey, Salvatore Cataldi, November 2020.
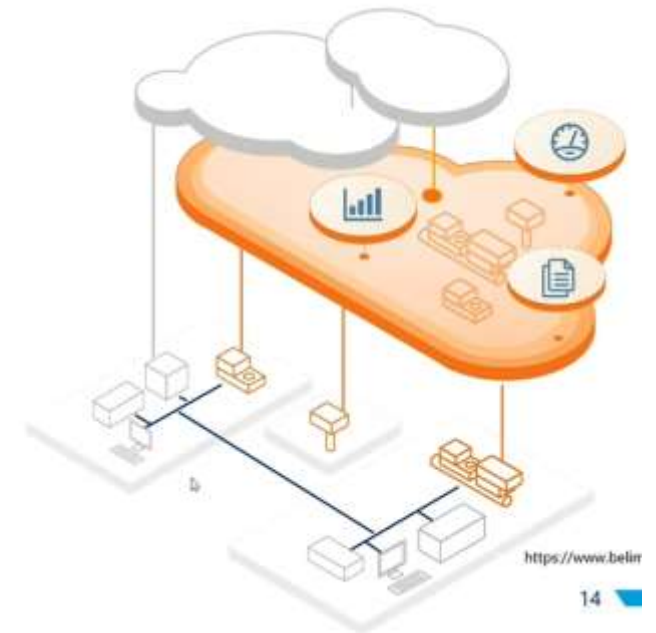
Building-IOT domains
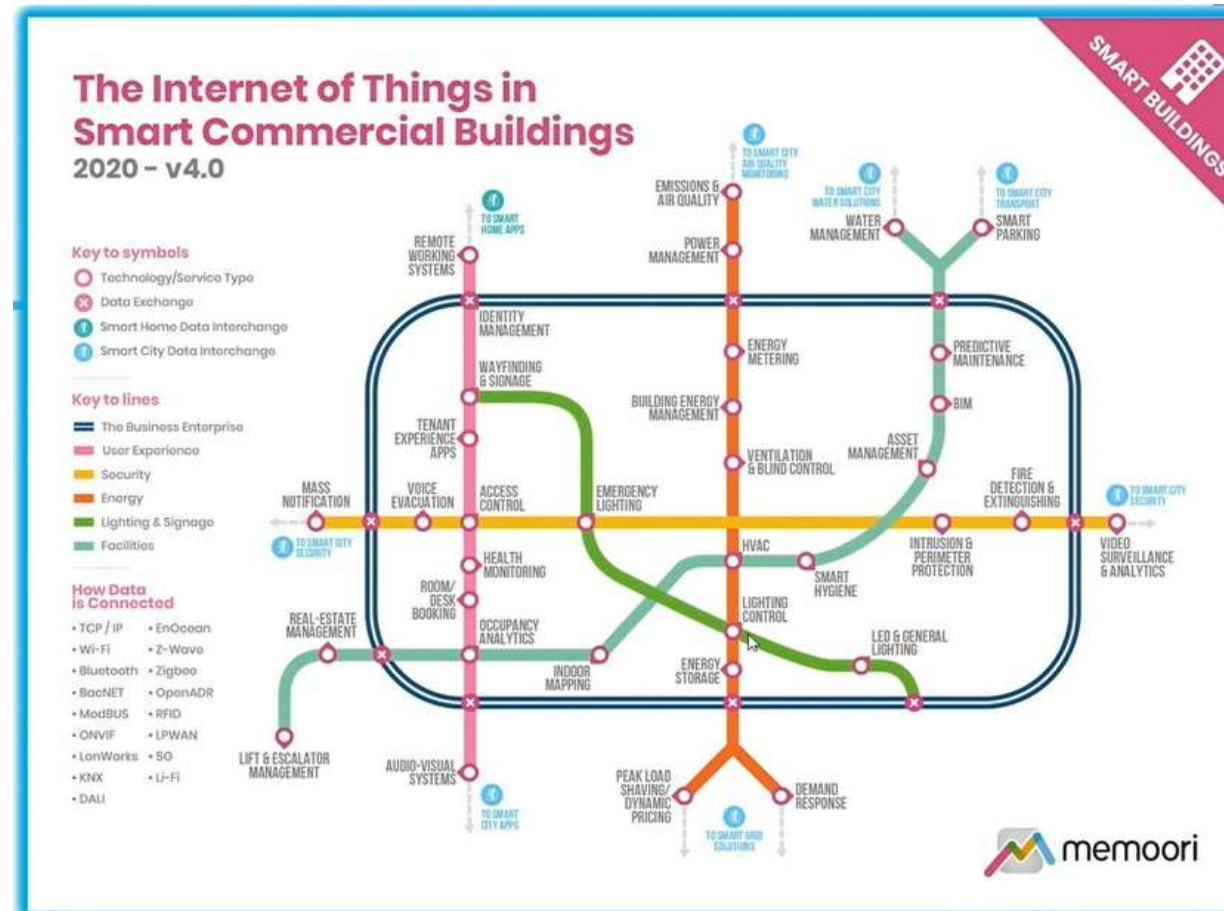
Cybersecurity

Identity and access to information.

- The digital twin and the real device are intimately connected.

- Just as we protect the real device, we must protect the digital twin

- Cybersecurity is an iterative process throughout the life of the building.

- Some of the weak points of a digital ecosystem:
  - The user
  - The installation

Cybersecurity

NIST Cybersecurity Framework 1.1

Identify → Protect → Detect → Respond → Recover

The search engine for **Refrigerators**

Shodan is the world's first search engine for Internet-connected devices.

Explore the Internet of Things
Use Shodan to discover which of your devices are connected to the Internet, where they are located and who is using them.

See the Big Picture
Websites are just one part of the Internet. There are power plants, Smart TVs, refrigerators and much more that can be found with Shodan!

Monitor Network Security
Keep track of all the computers on your network that are directly accessible from the Internet. Shodan lets you understand your digital footprint.

Get a Competitive Advantage
Who is using your product? Where are they located? Use Shodan to perform empirical market intelligence.

- What has favoured in building automation, the affirmation of the concept of the software objects and in general of object-oriented protocols

- The miniature and improvement of controller performance.

What has favored, in building automation, the affirmation of the concept of the software objects and in general of object-oriented protocols.

Asked by **Salvatore Cataldi** about a minute ago 🔒 Private

○ **The need to create sets of objects**

○ **Most modern programming techniques**

○ **The miniaturization and improvement of controller performance**

Interoperability

- The picture shows the items which are open.

What is it?

The ability to interact with devices even from different manufacturers

- Sometimes it is confused with the concept of "OPEN", while interoperability represents something much more complex and much more valuable.

- A system is open when the manufacturer declares and describes what the communication interfaces are and what the behavior is.

- A system implements the concept of interoperability when all its components adhere to **known and widely accepted rules** for the implementation of different interoperations.

What is interoperability

- BIBBs(BACnet Interoperability Building Blocks)

How do we achieve it?

- At BACnet, interoperability is designed using BACnet Interoperability Building Blocks (BIBBs).
- BIBBs are defined by domains, for example, data-sharing or Alarm and Event Management.
- They are always in pairs, A and B.
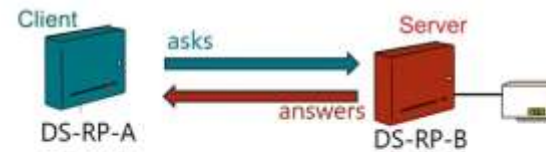
- BIBBs provide a standard identifier for the interoperability concepts supported by the devices

What is it?

The ability of products from different manufacturers to interact to perform tasks where such interaction was not specifically intended at product design time.

more on:
https://kilthub.cmu.edu/articles/Some_Current_Approaches_to_Interoperability/6584258

What is it for?

- To protect the investment in time, by extension or replacement
- To choose the right product without giving up integration with other systems
- To design applications before choosing products
- and much more...

21

Why do we need interoperability?

Why do we need it?

Take advantage of Synergies

- Being able to design interactions between different devices means also being able to take advantage of the cooperation between devices belonging to different domains

- For example, the same motion sensor can be used for HVAC, lighting and security.
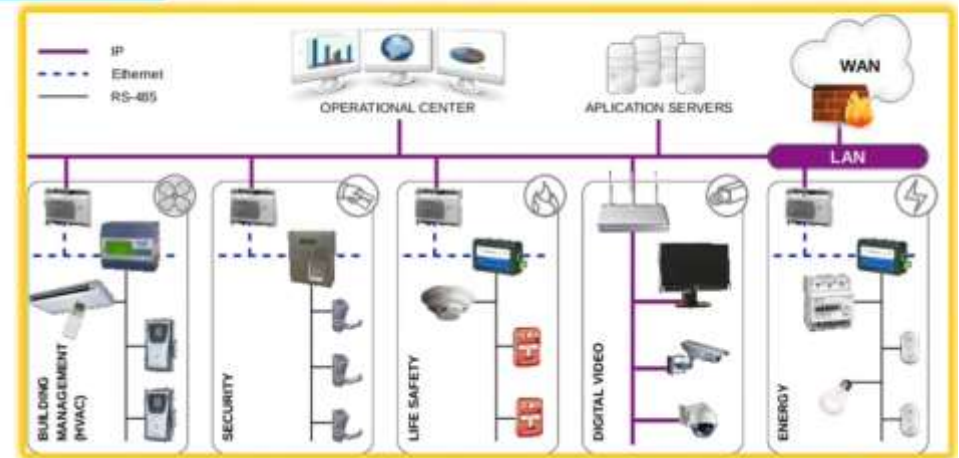
Traffic Measurement and Analysis of Building Automation and Control Networks 06.2012

Interoperability is all about standards

Standards

Known and (often) widely accepted rules

- There are many standards in building automation.

- The reasons for the proliferation of different standards on the same subject must be sought in the different experiences and objectives of the Committee that promotes each standard.

- However, the reason why a standard is developed is always the same: at a certain point in the evolution of a technology it becomes more advantageous to stick to a standard than to implement proprietary solutions.

Interoperability-standards-iso interdependencies

- BIM(Building Information Model)

Building Automation according to ISO

- My Building automation is completely ISO certified and now, with that ISO stamp on every aspect; I can sell my product at better prices.

ISO 16484-5 (BACnet)

Building automation according to ISO

- The impact of the building automation system on energy consumption is calculated using ISO 15232

- ISO 15232 refers to ISO 16484-3 in which automation functions are described.

- ISO 16484-3 refers to the objects and software functions standardized in ISO 16484-5.
This is the BACnet communication protocol for interoperability between components of a BACS.

ISO 15232

ISO 16484-3

ASHRAE 135
ISO 16484-5

BACnet

25

- The use of established and widely accepted standards facilitates interoperability

- Yes, because the devices implement the same standard which are understandable to everyone, except for the proprietary features

🔊 proprietary

/prəˈprʌɪət(ə)ri/

adjective

1. relating to an owner or ownership.
   "the company has a proprietary right to the property"

2. (of a product) marketed under and protected by a registered trade name.
   "proprietary brands of insecticide"

The use of established and widely accepted standards facilitates interoperability

Asked by **Salvatore Cataldi** about a minute ago 🔒 Private

○ Yes, because the devices that implement the same standard are understandable to everyone, except for the proprietary features

○ No, because it is not possible that everyone applies the same standard

○ Yes, because the proprietary features are useless

The digital puzzle
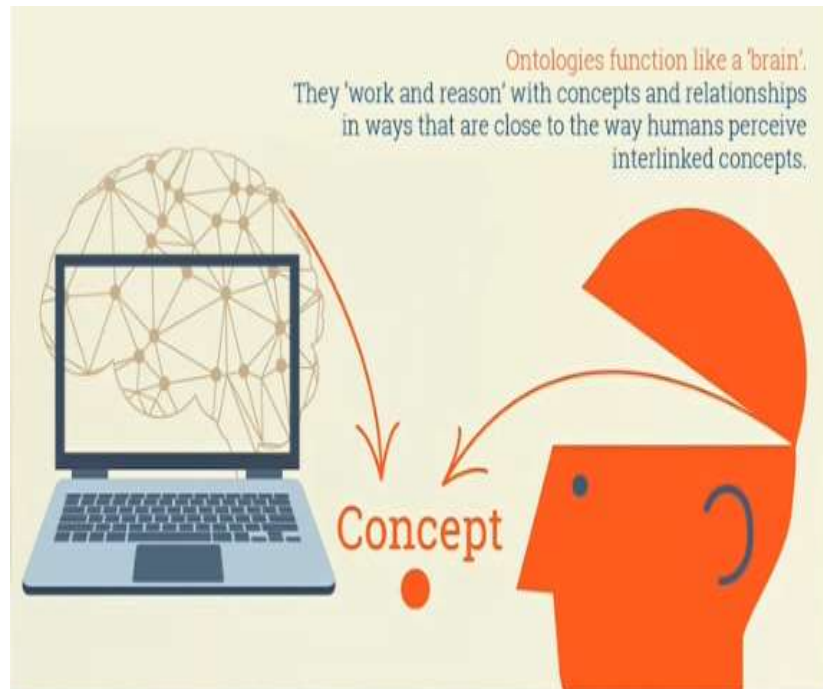# HVAC in the digital age

The Digital Puzzle

HVAC in the digital age

- The challenge is: to build the tools needed to maximize the benefits of digitization

- The advantages that we can imagine today are many and justify more and more important investments...

- But, as in every technological revolution, the more we will go ahead in choosing and putting in place the pieces of the puzzle, the more we will discover advantages that today we can not yet imagine, and this is much more important.

Chuck Gulledge
2020-2021 ASHRAE President
question what can I do to deliver a bountiful

ASHRAE's 2020-21 Presidential Address, Charles E. Gulledge
https://youtu.be/Pz4iSCDDiG0?t=1833

Ontology and mixing of different ontologies

Ontologies function like a 'brain'.
They 'work and reason' with concepts and relationships in ways that are close to the way humans perceive interlinked concepts.

Concept

28

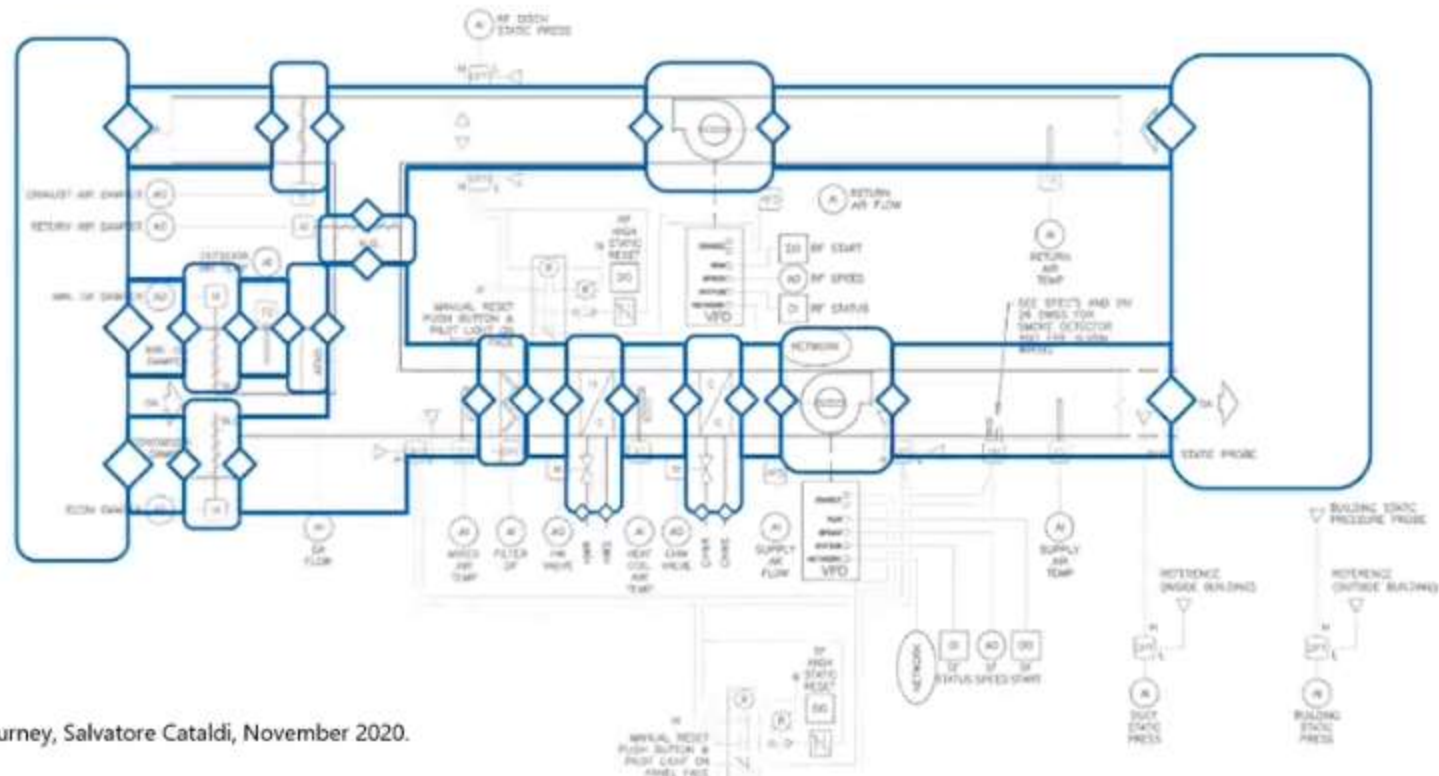## **Ontology Driven**

Knowledge Driven!

- An ontology is a formal description of knowledge as a set of concepts within a domain and the relationships between them.

- Thanks to the use of software called Reasoner it is possible to further elaborate an ontology and discover (inference) relationships not previously known. Therefore new knowledge.

- Ontologies related to different domains can be combined and reveal further knowledge for direct relationships between elements of different domains and for inference.
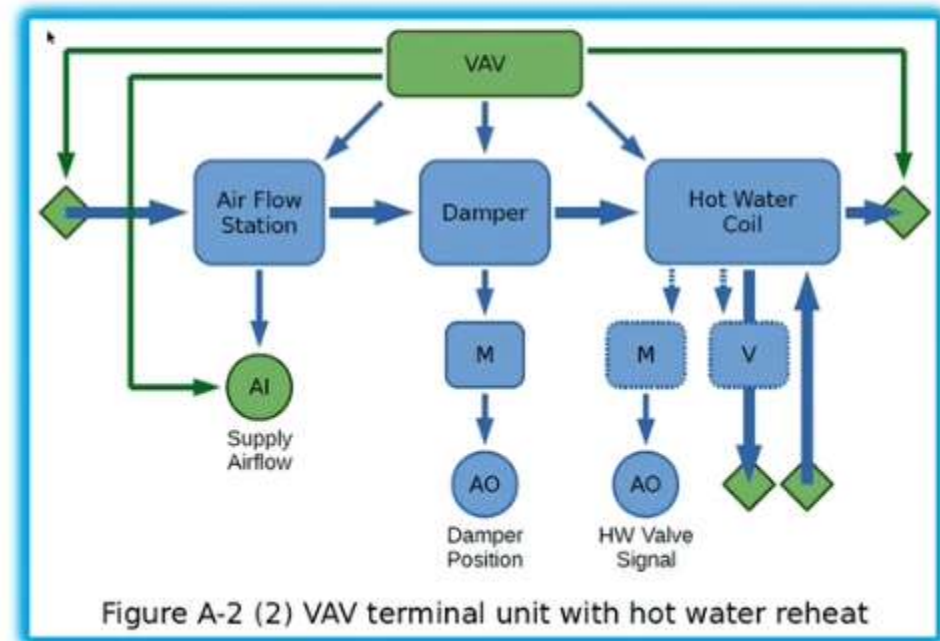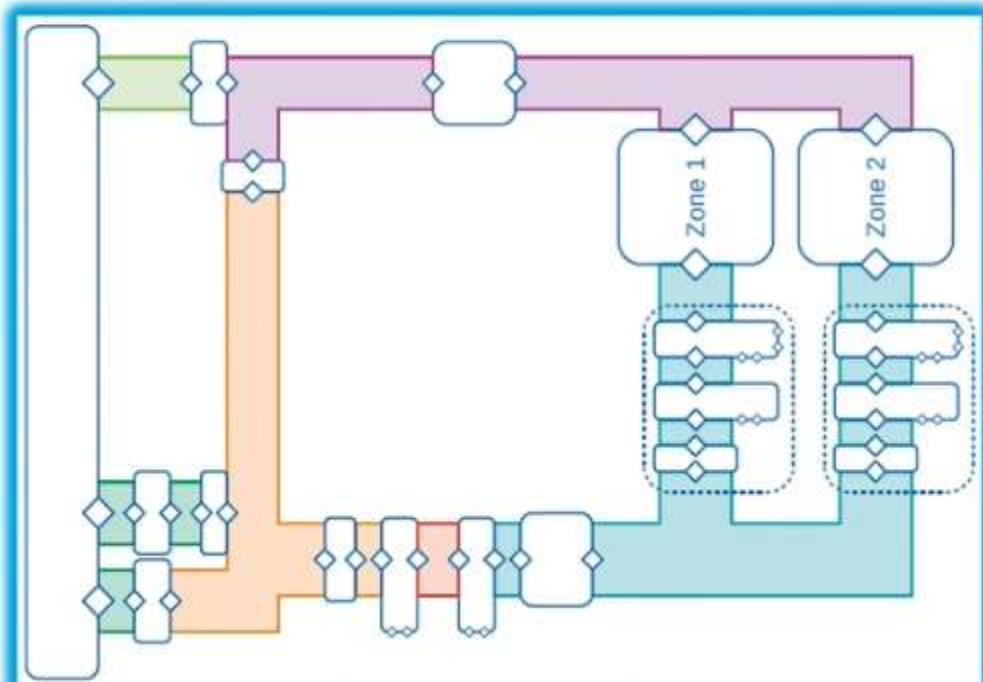
28

ASHRAE 223

ASHRAE 223

Figure A-2 (2) VAV terminal unit with hot water reheat

Ontology contd..

Ontology Driven

Ontologies for each domain foundation of autonomous control

- Any concept that can be described in an ontology becomes "understandable" for automatic processing.

- There is a very large and growing number of ontologies for the most varied domains.

- For example: the ontology describing the building and the ontology describing the control system can be merged and a reasoner with machine learning functions can be applied to the result of the merging.
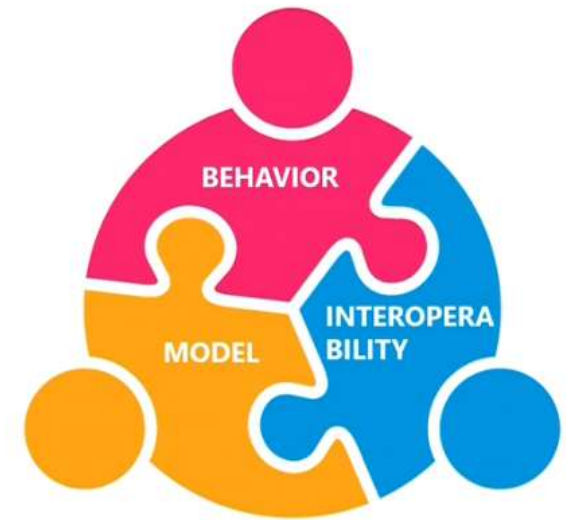
Digital Puzzle Summarization
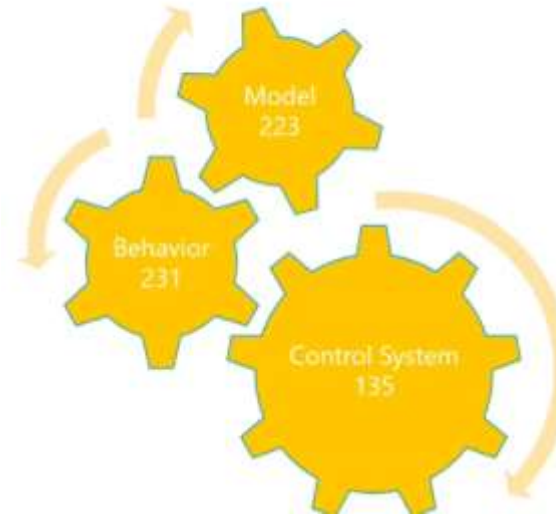
Il Digital Puzzle

Fundamental topics

In HVAC digitization they are three:

1. **Semantic Model**: the semantic representation of the HVAC system and its components

2. **Behavior**: information processing

3. **Control System**: how the components communicate with each other to form a system

- Each theme is implemented both with real and digital artifacts

- It is not possible to discuss one topic without considering the other two.

BEHAVIOR

INTEROPERABILITY

MODEL

How to solve the digital puzzle

- ASHRAE has implemented certain standards within their organization. After formal standardization they connect the ISO to make it global or whatever

How to solve the digital puzzle

ASHRAE Standards

ASHRAE has identified three standards as key tools for tackling the digital puzzle:

1. **Semantic Model**: 223, on semantic interoperability, it will show how to build semantic models of HVAC systems

2. **Behavior**: 231, to develop the standard Control Description Language for control sequences in building automation

3. **Control System**: 135, BACnet, on digital communication at every transport level and the representation of digital information.

The digital journey *is about people!*

Take-home messages

- the HVAC industry is constantly evolving.

- Building-IoT can be an extension of the BMS

- Digital Twin plays a critical role in Building-IoT

- Different domains are integrated

- The future is digital.

- The standard protocols used by Transport Layer to enhance its functionalities are **TCP**(**Transmission Control Protocol**), **UDP**(**User Datagram Protocol**), **DCCP**(**Datagram Congestion Control Protocol**) etc.

- BACNET(Building Automation and Control Network) is also a TCP protocol. It treats item as objects.

- Modbus is also a TCP protocol which uses items as list of memory registers

- EU standard is eubac.

- Protocols of building Management, whatever is out there is based on specific goals. Yes, there is a competition between different protocols but mostly the protocols are specific goal oriented.